24-030

Efficiency of Carbon Sorbents in Removing Zinc from Mine Water: A Comparative Case Study of the Rothschönberger Stolln Water

Frank Amo Boateng
Nils Hoth
Marlies Grimmer
Festus Animah

ABSTRACT

One of the challenges of mining is the concentration of heavy metals it releases into the environment through a phenomenon called Acid Mine Drainage. Freiberg is no exception due to its long mining activities. The European Union proposes that all rivers and streams must be in a good ecological status by the year 2027 but this would be difficult for large water sources as it would be economically unviable. Consequently, the approach of treating these waters at point sources would be of immense help and hence this column experiment on mine water treatment with carbon sorbents to remove zinc form the Rothschönberger Stolln. For this experiment three resins namely, APTsorb, activated coke, charred fermentation residues (which was produced by the Freiberg University of Mining and Technology) were analyzed through a simple column experiment to determine their sorption capacities. Through their sorption capacity as this experiment seeks to ascertain: we are able to make suggestions scientifically on the best material among the three for the future design of a treatment plant for the RSS. After the experiment whereby a 10 ml peri glass column was used, material A: APTsorb showed the least adsorption capacity (0.01 meq/g) and this could be attributed to the fact that the resin works well under pre-determined parameters such as pH and surface area. Material B: Activated coke showed a better sorption capacity (0.53 meq/g) in comparison to the basis value used for this experiment. Material C: charred fermentation residue which was produced by the University showed the most efficient capacity of (1.69 meq/g). This in comparison with the value used as the basis for this experiment showed that material C (charred fermentation residue) is very efficient for zinc sorption. pH values measured at the effluent of all the experiment were slightly higher than the pH measured in the initiating water.

INTRODUCTION

The Freiberg ore deposit is a zinc–lead–silver vein deposit. The geology of the Freiberg mining district is such that it is located in the central part of the Freiberg ore deposit and includes largely medieval mine works. These medieval mining activities have led to the metal concentrations in outflows of dewatering galleries and the Rothschönberger Stolln is no exception. In some top soil areas of the Freiberg area, even concentrations of some heavy metals can be located (Bayer, 1998). The European Union's 2002 Water Framework Directive indicates unequivocally that all flowing waters must be brought to an ecologically good to a very good status by 2027. This goal has become a far-fetched goal due to the economic difficulty in treating large rivers.

Nevertheless, "Grief 2013" indicates that another approach to the treatment of large water bodies is to treat it at point sources. Heavy metals generated through old mining activities could have low concentrations but upon accumulation could amount to tones of concentrations and hence becoming harmful. The aim of this work is therefore to test with different carbon-based materials for their ability to take up zinc from highly concentrated solutions by means of sorption processes using the RSS waters. The

Rothschönberger Stolln is a drainage channel which reaches a length of about 30 km from the Sächsische Brand Erbisdorf via the Freiberg mining district to Halsbrücke and from there to the mouth hole at the Triebisch near Rothschönberg. Construction of the tunnel began in

1844. The section of the tunnel from Rothschönberg to Halsbrücke was financed by the state. In the remaining section of the tunnel, the mines concerned were responsible for the construction of the tunnel themselves. For the construction of the adit, seven auxiliary shafts (so-called light holes) were sunk on the state side (fiscal part) in order to drive the adit from them in two directions per light hole in the opposite direction. In the case of counterdriving, the tunnel is driven from two directions. The RSS today can be identified as the main drainage structure of the Freiberg mining district (Bayer, 1998). Water from the mine field leaves the Freiberg gneiss and flows under agricultural land, mainly through a phyllite environment. Above the level of the RSS, the water is primarily oxygen-rich, but below this level it is mainly characterized by only a process that are chemical based. It is discovered that about one sixth of the Zinc load in the Elbe comes from the Freiberg Reiche-Zeche – which is also connected to the RSS. Consequently, heavy metals from the flooded part of the Himmelfahrt discovery mine together with organic contaminants also influence the RSS (Kluge et al., 1995; Kolitsch et al., 2001).

MATERIALS AND METHODS

A. Materials and Analytics

1) APTsorb

This is a commercial product and has achieved lots of success in the waste water treatment industry. For this research work it was able to provide a good control as it has proved in many researches. These granules normally keep their structure when wet and is adaptable hence making it able to be sized into many forms. The media has also a big surface area that is expected to help capture back suspended materials. In the Soudan Mine case, preceding small scale tests shows that this media can remove both suspended and dissolved copper from the mine drainage (Eger et al., 2009).

2) Activated Coke

This material was produced by a Carbon consultancy company in Germany specialized in carbon services. For privacy reasons, the name cannot be given. The mechanisms of sorption for this product are chemical (ion-exchange, chemisorption, complexation), physical (surface adsorption) and the combination of adsorption-complexation (American Peat Technologies, 2015)

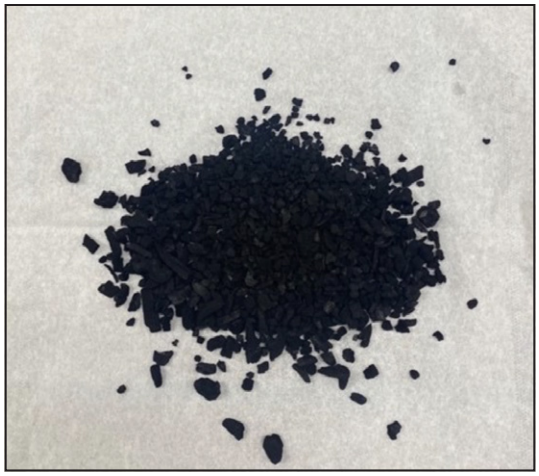

Figure 1. activated coke from a carbon consultancy firm in Germany

3) Charred Fermentation Residue

This material was produced at an institute at the Freiberg University of Mining and Technology but cannot be mentioned due to privacy reasons. The material is produced by a heating process.

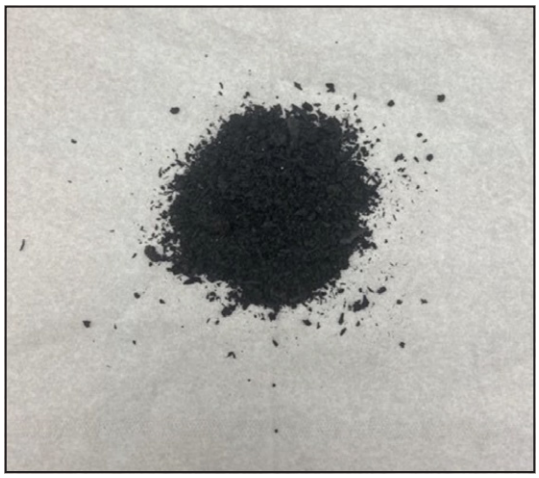

Figure 2. Charred fermentation residue

4) Experiment Water Source

For this experiment the water source used is the Rothschönberger Stolln. Direct water was sampled from the drainage channel and investigated with some carbon sorbents without pre – treatment of the water. The resulting ion concentrations were analyzed by the Microwave Plasma Atomic Emission Spectrometer (MPAES) and also milieu parameters measured, the adsorption capacities of the sorbents (APTsorb, activated coke, some charred fermentation residues from the University) were separately analyzed from the loading to the breakthrough point. Not only Zinc was considered, but also all elements which were present in orders of magnitude above 5% of the zinc ion concentration. This includes the elements Ca and Mg. The table below shows the various dates at which the water was sampled and their respective ion concentrations.

Table 1. Mass fractionally relevant ion concentrations at various water sampling time

Date	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	Mn (mg/L)
23.06.22	3.12	128.9	25.9	36.9	0.61
04.08.22	3.3	150	27.1	47.3	0.55
11.08.22	2.82	152	26.2	47.2	0.52
14.09.22	3.57	122	25.6	45.3	0.51

B. Methods

1) Literature research on active plants for comparison (The Soudan Mine Experiment by (Eger et al., 2009)

This paper gave the database of the whole study of the Soudan Mine – helping in understanding even the relevant costs and economic profits in relation to them adapting this method of water treatment. Furthermore, the previous research work conducted by students at the Mining faculty on carbon sorbents also provided some information for this literature work.

2) Column Experiments

In a column experiment, a Plexiglas column of 10 ml capacity was selected for this experiment. Each resin to be investigated was loosely placed inside the column. Due to the size of the column the same weight of the resin was not attained because they have different densities. The table below shows the mass of materials used for the different experiments. For the three different experiments, the required mass of the resin was stuffed in the column to get the desired height of the bed. A layer of glass wool was put below the glass column to allow just the water to pass through. Also, a glass wool was placed at the cap of the glass column also to prevent the resin from coming out of the column. The sample source for the experiment (RSS water) which had different pH (7.6, 7,4, 7.30) at the different times of sampling was pumped upward at the flow rate which has been calculated by using the peristaltic pump model IPC from Ismatec®. At regular intervals due to sampling, the water that comes at the outlet was collected and this was made possible using the Autosampler manufactured by the University. The residual concentrations were measured using photometry and MPAES.

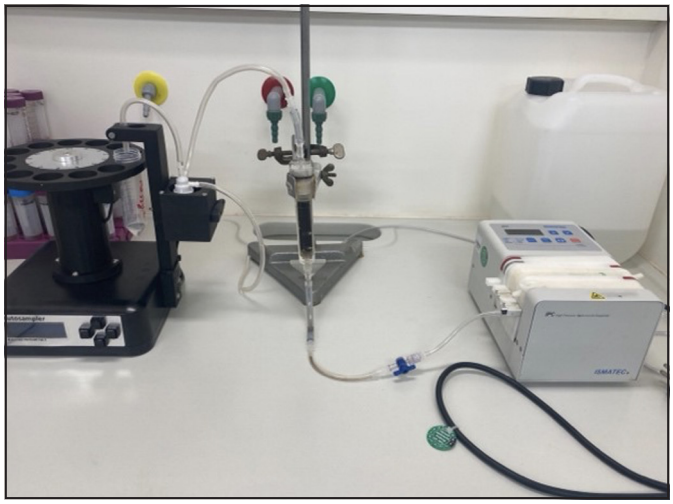

Figure 3. Set-up of the small column experiments with an auto sampler manufactured at the TU Bergakademie Freiberg(left), filled column (center) and a peristaltic pump (right)

To start the experiment, it was necessary to avoid contamination and hence the whole tubing was filled with distilled water before each of the three experiments. This process possibly helps us to determine if factors like the pH of the solution is influenced only by the material or whether the material releases material into the water. After the entire system was filled, the experiment was continued with the initiating solution and the autosampler was switched on. A peristaltic pump with planetary drive, model IPC from Ismatec® was used to pump the sample liquids. In determining the flow rate for this experiment, the tube diameter in the pump was essential. For this diameter, the pump presets the flow rate range in ml/min to enable the speeds to be set. For a velocity of 80 ml/h required for this experiment, it corresponds to a set velocity of 1.33 ml/min which is equivalent to 1BV/h.

Table 2. Table showing the various Resins used for the experiment and their respective masses

Name of Resin	Mass Used (g)
APT (sorp). (A)	7g
Activated Coke (B)	5g
Charred fermentation residue(C)	2,55

3) Calculating Adsorption and Desorption

Table 3. Equations used for calculating adsorption and desorption of the resins

Parameter	Equation	
Total adsorption of X^{th} ion in loading process (A_x)	A_x	(1)
Bed volume difference (B_{xi})	$B_{xi} = BV_i - BV_{(i-1)}$	(2)
Total adsorption of X^{th} ion in mili equivalent $(A_x)_{meq}$	$A_{xmeq} = A_x/M_x * Vx$	(3)
Total desorption of X^{th} ion in Regeneration process (D_x)	$D_x = \sum^n (Cxi\ Vi)\ i = 0$	(4)
Total desorption of X^{th} ion in mili equivalent	$D_{x(meq)} = D_x/M_x * V_{ex}$	(5)
Percentage recovery (R%)	$D_{x(meq)}/A_{x(meq)} * 100$	(6)

where,

C_x feed = concentration of the ion x in the feed solution

C_{xi} = concentration of the ion x in the ith bed volume

BV_i = Bed volume number of ith sample

$BV_{(i-1)}$ = Bed volume number of the (i–1) sample

M_x = atomic weight of the element x

V_{ex} = valency of ion x

C_i = concentration of the i^{th} sample

V_i = volume of the i^{th} sample

III. RESULTS

A. Results of the Soudan Mine in Minnesota

This is the case of the first iron mine in Minnesota which has been operating since 1963. The mine is known to have a depth of about 730 m and some 18 levels (Eger et al., 2001). A 3,800 L pressurized tank containing 1,900L of the peat-based sorption media was designed. This was meant to allow the media to be freely backwashed to discard particulates. The water enters through the top lateral outlets, comes down through the media into the gravel collection unit and exits through the bottom lateral outlets. The backwashing is then done by simply turning back the flow. This experiment has treated more than 32,000 bed volumes. We must appreciate that the total number of bed volumes is correlated to volume of water being treated.

B. Result of the Small Column Tests 1) Experiment A: APTsorb

The APTsorb material must be in a wet condition to be directed into the column (Dorfner, 1963). The measured values of zinc concentration show that after 18BV and 35BV, the initial value of the zinc in the solution is reached and even surpassed. Previously, the curve for zinc shows a small slope. Between 2BV and 18BV, the zinc content in the solution rises quite sharp even flattening from BV18 and BV35 rising to the initial concentration before it falls steeply. Initially, the pH is 7.4 but as the experiment goes further, the pH finishes just slightly above 7.4. We can also see from the graph that the Eh increases just around the 18BV and 35BV where the zinc concentration is higher even above the initial concentration. This means that the zinc precipitated due to the solution being in an oxidation zone. The Eh curve further reduces along as the zinc concentrations also reduces showing less precipitation and more zinc in solution. This is true for standard zinc because it will always be in a reduced form.

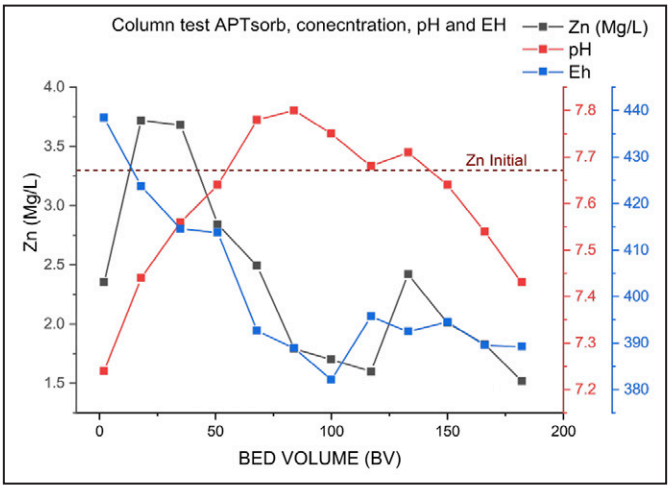

Figure 4. Result of the APTsorb resin with respect to Zinc concentration, pH and Eh

When we look at the graph, we realize that breakthrough was achieved over the entire experiment after the flow through of 2BV. The total adsorbed zinc was 1.785 mg and the total desorbed zinc was -0.068 mg all corresponding to an adsorption capacity of 0.01 meq/g for the material. This capacity is very less compared to what is provided by the manufacturer which is 0.45 meq/g. Also in comparison to Lisa Johnke who worked with similar material

and got a sorption capacity of 0.127 meq/g we can say the expansion of the granules during the test could have prevented the optimal flow around them.

2) Experiment B: Activated Coke

The concentrations of zinc ions begin to increase from the first sampling of the sorption phase and increases to around 2.2 mg/L until it fluctuates until it reaches the highest values of 2.99 mg/L and 3.41 mg/L. During the initial phase, the pH value starts form 10.2 at the 2BV. The value then stabilizes at the value of 8 and this is carried through to the end of the experiment. The Eh value is as well at the highest corresponding to the highest value of the Zinc concentration of 3.41. This means that the zinc was precipitated at that point due to the oxidation state of the solution. Meanwhile, we see the lowest Eh value also corresponding to the lowest values of the zinc concentration indicating more zinc in solution in a reduced state.

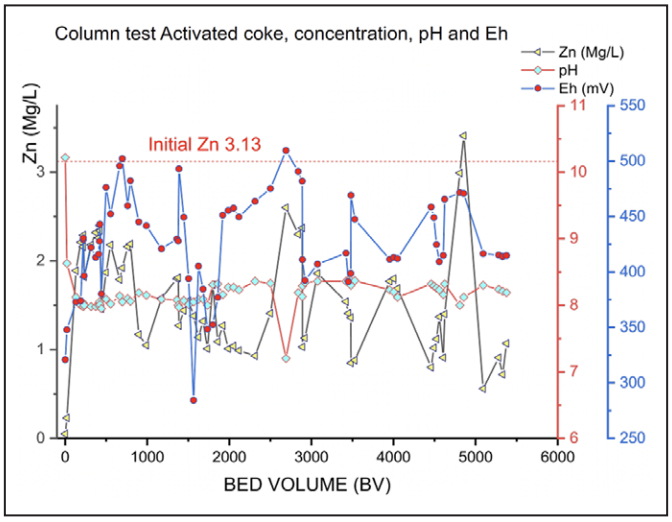

Figure 5. Results of the column experiment B with respect to Zn, pH and Eh

At the end of the experiment at BV5376, a total of 87.00 mg Zn/g was adsorbed and -0.001 mg Zn/g desorbed. A total of 53 liters of water was treated for this experiment. This corresponds to a capacity of 0.53 meq/g comparing to Lisa Johnke who worked with similar material and attained a capacity of 0.61 meq/g. It can be surmised that the material is good in comparison to the capacity value obtained by Lisa and in this experiment. The material shows a breakthrough just at the 2BV of the sorption phase indicating an affinity of the material to adsorb zinc.

3) Experiment C: Charred Fermentation Residue

The experiment breakthrough at the 2BV with a Zn concentration of 0.09 mg/L and maintain a steady concentration through until 1668 BV where the concentration begins to rise. This material shows a very meaningful curve with consistent values. At the same time the pH starts with a value of 8.0 and at the time the experiment is stopped, a pH of 8.35 is recorded. The pH value as it rises from 8 drops to 7 steadily around the middle part of the experiment before it rises again to 8 It can be inferred the breakthrough curve lies slightly below the Eh curve indicating a more dissolved zinc in solution.

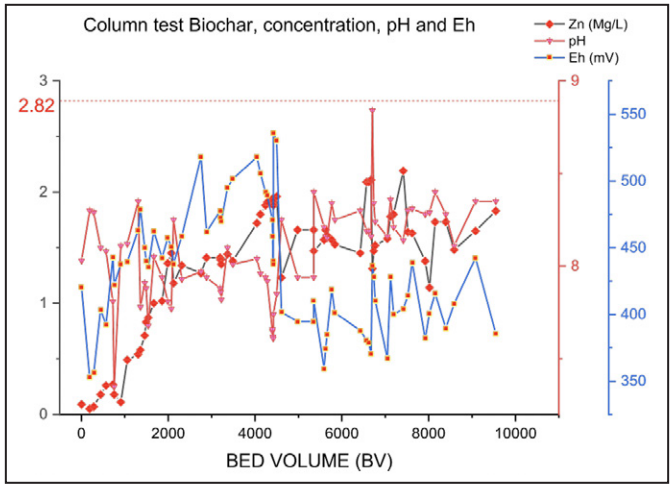

Figure 6. Results of the column experiment C with respect to Zn, pH and Eh

With respect to zinc a breakthrough was achieved at 2BV and taking into account the MPAES error of 5%. Throughout the entire experiment from sorption phase to breakthrough, a total of 140.92 mg of Zn was adsorbed representing 4.3 meq of Zinc. This correlates to an adsorption capacity of 1.69 meq/g. comparing this to the adsorption capacity (1.55 meq/g) of Lisa Johnke with the same material from loading to exhaustion, it can be inferred that the material is able to reach a full capacity.

C. Zinc Adsorption of Materials in Relation to Their Capacities

The summarized results of the column tests with regard to their sorption of the zinc as shown in Table 4.

Looking at the result of the experiment we realize that the amount of zinc adsorbed was different for every material. For the material A- APTsorb, the zinc adsorption was

Table 4. Results of the sorption of Zinc in the experiment

Material	Name	Sorbed zinc absolute [mg]	Desorbed zinc absolute [meq]	Sorption capacity [mg/g]	Sorption capacity [meq/g]
APTsorb	A	1.75	–0.068	0.25	0.01
Activated coke	B	87.00	–0.037	17.40	0.53
Charrred fermentation residue	C	140.92		55.263	1.69

0.01 meq/g and was the lowest. However, the surface area of the material wasn't increased and that compared to Lisa Johnke's second experiment was low - which the surface area was increased. Material A proved very ineffective for this experiment and we could conclude that perhaps it works perfectly under certain perfect adjusted conditions such as pH.

The material B—Activated coke showed a capacity of 0.532 meq/g which was the second highest among the three materials. This also compared well with the adsorption capacity achieved by Lisa Johnke who had a value of 0.61 meq/g. The material C – Biochar from the residues and produced by the University showed the greatest capacity of 1.690 meq/g and it must be noted that the experiment didn't get to exhaustion due to inadequate time. This means that the material C is very effective for the removal of zinc

D. Results of the Breakthrough Curves of Zn

The breakthrough curves also predict the effectiveness of the materials. It can be seen that the material C shows a perfect curve that is progressive from 2BV and stabilizes around the BV44. For all the experiment a quicker breakthrough was achieved mostly just after the sorption phase at 2BV. Material A and B showed desorption in the experiment indicating precipitation of the zinc at some points in the experiment particularly when the initial concentration of the zinc was exceeded at the exhaustion points. The breakthrough curves are shown in Figure 7, 8 and 9. From the breakthrough curve of the material A- Activated coke, we notice a very fast breakthrough with a high zinc concentration value of more than 50% the initial concentration zinc. It also reaches exhaustion just after the 18 BV which was the third sampled.

E. Breakthrough Curves of Other Main Elements and Its Influence on Adsorption Capacity

1) Experiment A: APTsorb

Considering Table 1 we see that the initial concentration of Ca being 150 mg/L was not reached in this experiment but rather there is a desorption of the Ca from the beginning of

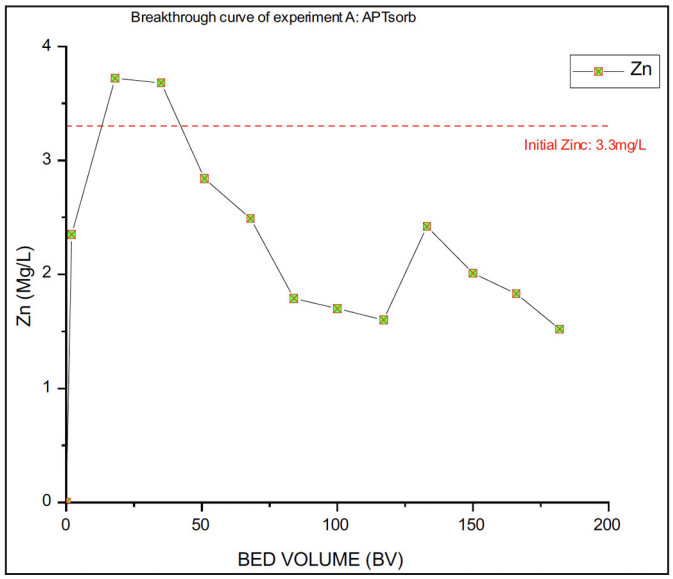

Figure 7. Breakthrough curve of Experiment A

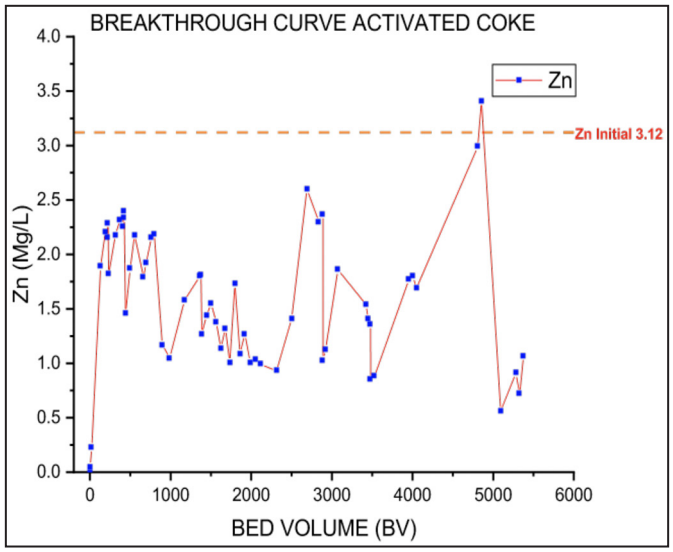

Figure 8. Breakthrough curve of Experiment B

the experiment at a concentration of 141.64 mg/L until it reaches 128 mg/L. The material desorbs Mg which has an initial concentration of 27.1 mg/L but this initial concentration is not reached as it desorbs from 36.56 mg/L at the

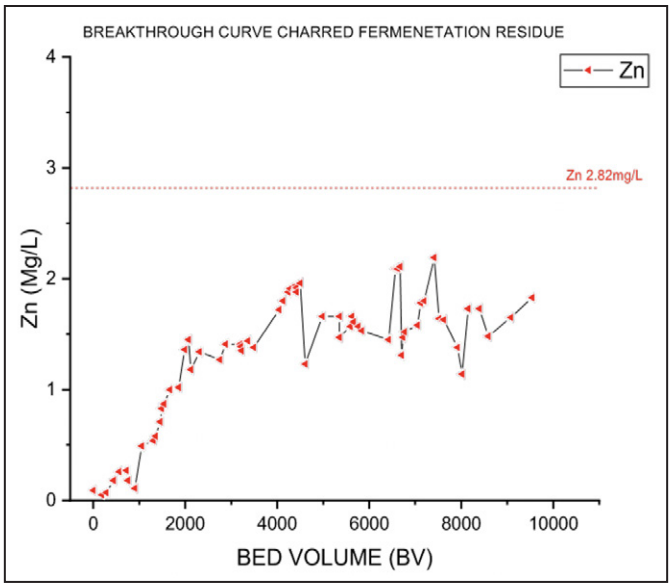

Figure 9. Breakthrough curve of Exeperiment C

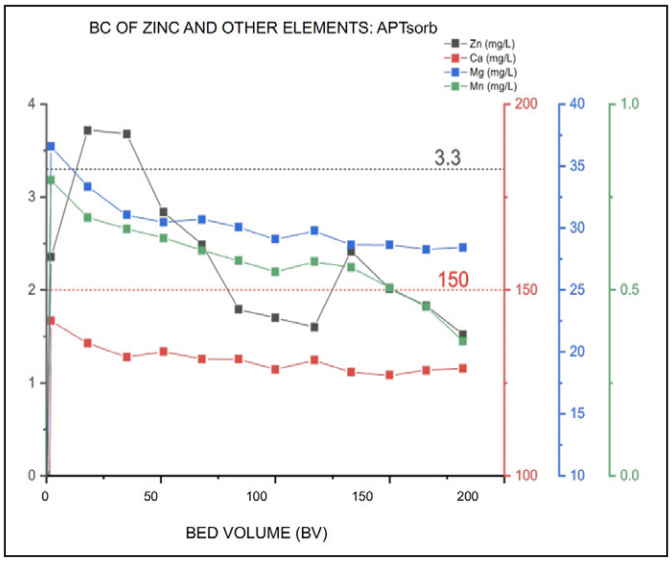

Figure 10. Breakthrough curve of zinc and other elements

2BV. Mn which has an initial concentration of 0.55 mg/L starts with concentration 0.79 mg/L at the 2BV and desorbs until it reaches a concentration of 0.362 mg/L. The higher desorption of Ca and Mg only shows there were a comminution of the material and that the access to the respective ions was made easier.

2) Experiment B: Activated Coke

In this experiment we notice that about 75% of the total BV, the Ca concentration exceeds its initial concentration of 128.9 mg/L before it lowers back to around 95 mg/L. A

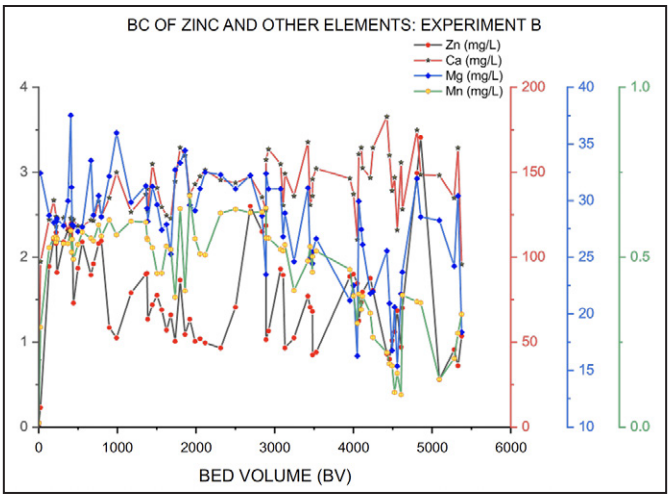

Figure 11. Breakthrough curve of zinc and other elements: Activated coke

similar situation happens with Mg resulting in a rise of its curve. The initial concentration of 25.9 mg/L is reached at around 75% of the total BV after it desorbs from a higher concentration of 32.41 mg/L. This shows a sorption of Ca and Mg right from the sorption phase of the experiment. There is also adsorption of Mn as it starts at a concentration of 0.012 mg/L and rises sharply until it exceeds the initial concentration of 0.61 mg/L. Although a correlation of these elements and the zinc sorption could not be observed, it can be inferred that these adsorptions impacted slightly the adsorption capacity of the material due to the ion exchanges between the Ca, Mg and the Zn. This material therefore has the affinity to adsorb the elements Ca, Mg and Mn.

3) Experiment C: Charred Fermentation Residue

From this graph it can be observed that whose initial concentration in the initiating solution being 152 mg/L starts very high and rises steadily before reaching back to the initial concentration and lowers back to 127.9 mg/L. Mg on the other hand also adsorbs very little at the sorption phase of the experiment but rises through reaching back to its initial concentration of 26.2 mg/L before rising further and above it. The curves of the Zn, Mg and Ca are very similar in this regard and all show adsorption. The material seems to sorb Mn at the initial phase but very little and throughout the experiment it begins to desorb from the initial concentration until the concentration reduces. This affinity to adsorb Mg and Ca as well as Zn in higher concentrations without seemingly affecting the running time of the material only confirms it's a very good material.

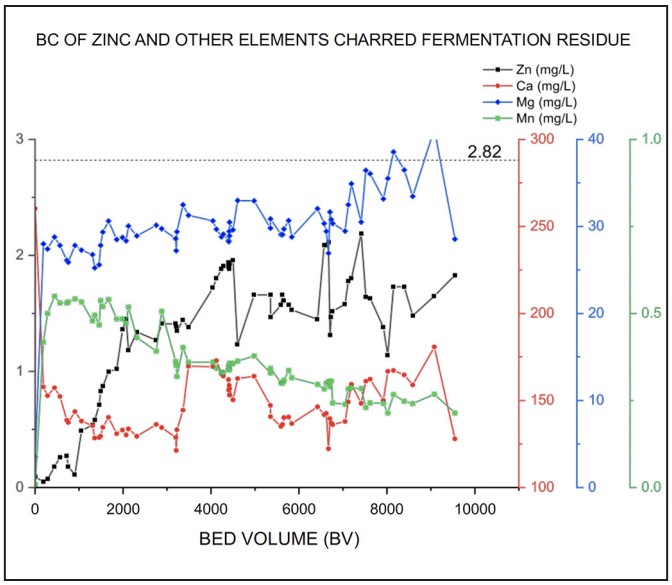

Figure 12.

IV. DISCUSSION

A. Comparison of Experimental Result and the Soudan Mine experiment

Comparing the results of this experiment to the Soudan mine experiment result, it can clearly be noticed that in this experiment APTsorb had a very fast running time with a very low adsorption capacity of zinc. This premised the conclusion that it wouldn't be good for the design of a future RSS plant. Nevertheless, APT works better under specific preset conditions of pH and etc. For this lab work, there was no chemically or physically enhanced condition for the APTsorb. Also, in the Soudan mine experiment APTsorb was efficient for the removal of copper and cobalt with previous smallscale pilot tests showing that the media could remove both suspended and dissolved copper from mine drainage (Eger, Paulson and Green., 2008). Specialized pressurized tank were designed at the industrial level to enhance the performance of the peat media.

B. Comparison of the Results

In this experiment we realize that each material shows different suitability in terms of zinc sorption. The APTsorb material has the lowest capacity. The Activated coke from natural residues shows the second highest capacity. The Charred fermentation residues from the University has the highest capacity value and means it is very well suited for the sorption of zinc and in a continuous form clearly exceeded the benchmark value even though the experiment didn't end due to time constraints. Generally, the modifications made in the material B and C through the increase in their surface area by grinding proved to help in their adsorption. With respect to the breakthrough curves of the materials, the experiment C shows a better curve that is steeper. (Table 5)

C. pH and Eh Values of the Experiment

Throughout the experiment we noticed an increase in pH For the Activated coke and Biochar, a reason for the increase in the pH can be attributed to the alkaline ash content of the materials. Also, at the initial phases where distilled water was pumped through the column, a very alkaline measurement was recorded. Throughout the effluent pH values were higher than the initiating pH values. Standard zinc will always be in a reduced form and the Eh values showed throughout the experiment. The Eh values are very high whenever the Zinc concentration at exhaustion exceeded the initial zinc concentration indicating desorption. The Eh values at

Table 5: Comparison of the results from experiment and previous work done by Lisa Maria Johnke

Material	Sorption (mg/g)	Capacity	Sorption (meq/g)	Capacity Source
APTsorb			0.23	Lisa Maria Johnke
Activated Coke			0.61	See above
Charred fermentation residue			1.55	See above
APTsorb	0.250		0.01	This thesis work
Activated Coke	17.40		0.53	See above
Charred fermentation residues	55.263		1.69	See above

this point proved an oxidation state and a precipitation of the zinc.

D. Error Considerations

All the experiments were performed just once due to time constraint and for that reason measurement errors or errors in the experimental procedure may not be detected as such. It was also observed that not every material was homogeneous and this was observed in the grain size of the materials. The Activated coke material and the Biochar showed a very low density due to their sizes and which an enhancement was made by grinding to increase their surface area. The material C – Charred fermentation residues became very fine after the grinding. It could not be ensured that the composition of the materials in the columns and sample vessels was always the same. The material A had a high density and didn't require grinding since the required mass was able to fit the column. This may result in bias in the results of the column test.

Regarding the APTsorb material, it must be stated that it is designed for specific parameters like pH, maximum height to diameter ration (American Peat Technology, 2022). Hence the capacity attained points to the fact that the full potential wasn't reached due to the unavailability of these parameters set by the designer. For column experiments, an experimental design with columns with a diameter to height ratio of 1:10 – 1:20 is recommended according to (Dorfner, 1963). Based on this, the same column being used for all the experiments could help in the analysis. The MPAES equipment as well has a 5% error which could also affect the element concentration measurements. This was reflected in fluctuations in measurements at various instances. Through the charred fermentation residue experiment, the material compacted with its wet BV reducing to around 4BV. This must be considered in future experiment by using a bigger column a bigger mass of the resin.

V. CONCLUSION

The material called the charred fermentation residues had the highest sorption capacity of the zinc and also had a high affinity towards the sorption of Ca, Mg which were also present in the water but in lower concentrations. The second best material was material B (Activated coke). Material A (APTsorb) was the weakest in the adsorption of zinc and didn't show any affinity towards Mg, Ca and Mn. In a further detailed literature research, result on the present mine in Minnesota the Soudan mine was found on the usage of APTsorb for its treatment of AMD. It was found that by the usage of this material, the mine has made a significant economic profit due to the easy availability of this sorbent and also the larger volume of water its able to treat. Meanwhile, unlike this experiment where no conditions were chemically or physically influenced for the materials, with the Soudan Mine specially designed tanks with specific diameters were used to allow backwashing of the APTsorb. The objectives of this experiment were met and I would recommend that future experiments could be made on a larger scale using a bigger column and a faster flow rate to improve upon the work. Also, the sorption capacity for material C has to be fully investigated since it proved a very good capacity yet the experiment not finishing due to time constraints.

ACKNOWLEDGMENT

Data from this manuscript has been presented at the MINEXCHANGE 2024 SME Annual Conference & Expo, February 25–28, 2024, held in Phoenix, Arizona

REFERENCES

Agilent Technologies. (2015). Agilent 4200 microwave plasma atomic emission spectrometer It's in the Air. www.agilent.com/chem/runsonair (viewed 18.09.22).

American Peat Technology. (2022). How to Deploy APTsorb and APTIVATOR americanpeattech.com /sorption-medial/ (viewed on 18.09.22)

Bayer (1998). The Ascension Mine. A Guide to the Teaching and Visitor Mine of the TU Bergakademie Freiberg. TU Bergakademie Freiberg.

Dorfner, K. (1963). Ion exchangers – properties and applications. Walter & Co.

Eger, P., Johnson, A., and Wagner, J., (2001). "Investigation of Elevated Copper and Cobalt Concentrations in Soudan Mine Drainage," Minnesota Department of Natural Resources, Division of Lands and Minerals, St. Paul, MN, 36pp including appendices.

Eger, P., Jones, P., and Green D,. (2009). "Solving Mine drainage water issues with peat-based sorption media" Mining Engineering, 2016, Vol.68, No.2, pp. 38–43

Eger, P., Paulson, E., and Green D,. (2008). "The Use of Peat Pellets to Remove Copper and Cobalt from Mine Drainage." Proceedings of the 24th Annual Meeting of the ASMR, Richmond VA, 2008.

Kluge, A.; Martin, M.; Baacke, D.; Hoppe, T. (1995). The "Himmelfahrt Fundgrube" teaching mine of the TU Bergakademie Freiberg - a natural laboratory for hydrogeological and environmental geochemical research. Internet homepage of the Institute for Mineralogy of the TU Bergakademie Freiberg (www.mineral.tu -freiberg.de)

24-031

Engineering a Large Eco-Friendly Reinforced Sloped MSE Wall System to Increase the Size of a Flat, Work Area of a Mine

Carlos Andrade
Maccaferri, Inc.

An engineering endeavor involves the creation of an expansive, environmentally conscious reinforced sloped MSE wall system. The objective is to enlarge a flat mining work area. Situated in southern Arizona, this mine is dedicated to extracting essential resources such as Manganese, zinc, silver, and lead, crucial for advancing clean and renewable energy initiatives. The project necessitates the implementation of a Mechanically Stabilized Earth retention system. This system aims to both expand the mine's working area and facilitate access to underground tunnels.

The expansion pad must be robust enough to endure the substantial loads exerted by heavy mining machinery. The wall's reinforcement components are strategically designed to counteract the challenges posed by aggressive soil conditions with low resistivity. Furthermore, they must be resilient against potential damage during installation. The system's ease of transportation is crucial due to challenging access conditions, and its design must allow for efficient drainage.

A significant consideration is the integration of a face system that fosters vegetation growth and seamlessly merges with the existing flora of the area. In addition, plans include the construction of an access road downslope from the wall. The chosen solution involves a reinforced sloped system with a 70-degree incline. The wall's surface is adorned with an erosion control mat, intended to promote the proliferation of vegetation. For added durability, the wire basket units are equipped with galvanized wire featuring a polymer coating. High tensile strip bonded geogrids, featuring a robust polyester core, provide essential reinforcement.

The completed wall is an impressive feat, spanning 1500 feet in length and soaring to a height of 45 feet. It stands as a testament to innovative engineering in harmony with environmental and functional considerations.

SELECTION OF GEOSYNTHETIC REINFORCEMENT MATERIALS

The design parameters to be considered in the design of the MSE wall structure included a horizonal and vertical peak ground acceleration coefficients, CONEX Box Containers Loading capacity, and in situ backfill selection of highly corrosive soils.

A selection of Geogrid geosynthetics manufactured from high tenacity, multifilament polyester yarns aligned and co-extruded with polyethylene (LLDPE) to form Polymeric strips. The heavy LLDPE coating enable the Geogrid product to be used as reinforcement of contaminated and high aggressive materials for use in environmental applications. Different strengths of geogrid were used to accommodate height levels and loading, below is a chart of the products used:

Product Name	Tensile Strength (Ultimate)
Paragrid 65/5	65 kN/m – 4454 lb/ft
Paragrid 80/8	80 – 5482 lb/ft
Paragrid 100/5	100 kN/m – 6852 lb/ft
Paragrid 120/5	120 kN/m – 8222 lb/ft

SELECTION OF DRAINAGE COMPOSITE MATERIALS

The large expansion pad area would be subject to collect substantial amounts of rainfall, a proper drainage system for the wall was a key factor for the proper functioning of the MSE wall. A Geocomposite for planar drainage system (GCD), was selected. It is realized by thermobonding a draining core in extruded monofilaments (GMA) with two